Signal simulation and hit calorimetric reconstruction in LArSoft

D. Stefan (CERN/NCBJ), R. Sulej (FNAL/NCBJ)

Software & Simulation and *Physics Analysis* meeting, July 27, 2016

Introduction

- Previous tests: run existing reconstruction workflow in LArSoft, using workspace geometry of DP FD. Tests done to check if we are able to reconstruct tracks and display them correctly in event display.

- In this talk: basic checks of spatial and calorimetric reconstruction using higher statistic of simulated particles; required to have reconstruction output useful for analysis.

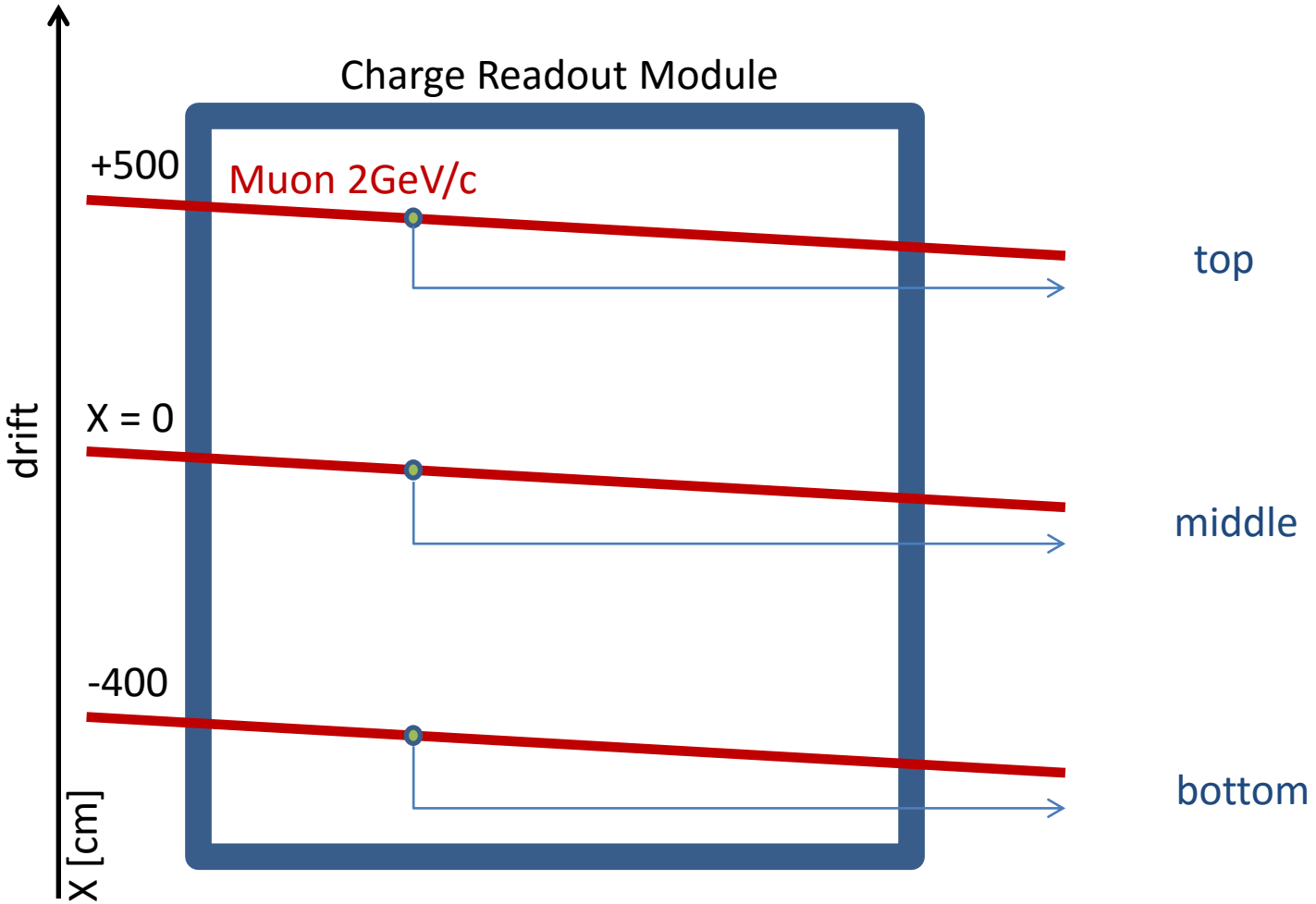
- The idea was to use minimum ionizing muons and find values of calibration constant in order to obtain correct dE/dx.

- Parameters of signal simulation and hit reconstruction in LArSoft were investigated: the ADC shape and hit finding behaviour was suspicious and we had to understand each step: we have learnt a lot.

Simulation/reconstruction

- Use the newest release of LArSoft version 6.
- 2 GeV/c simulated muons.
- Muons were simulated on the top, middle and bottom of the far detector to test hit finding/hit fitting performance for different amplitudes of signal.
- Electron lifetime: 3ms, as a default value in LArSoft.
- Noise has been switched off in order to limit the number of factors which can affect the signal processing algorithms.
- Reconstruction chain: gaus hit finder → linecluster (2D pattern recognition) → **P**rojection **M**atching **A**lgorithm (3D pattern recogntion and trajectory fit).

Muon simulation



Muon 2 GeV/c, Θ_{0XZ} = -8 degree, Θ_{0XZ}=-11 degree

- Electron lifetime: 3 ms
- Diffusion on

Signal simulation

energy deposition in voxels

ionization + recombination effect

number of electrons + light

electron lifetime

number of electrons

important for long drifts

drift & diffusion

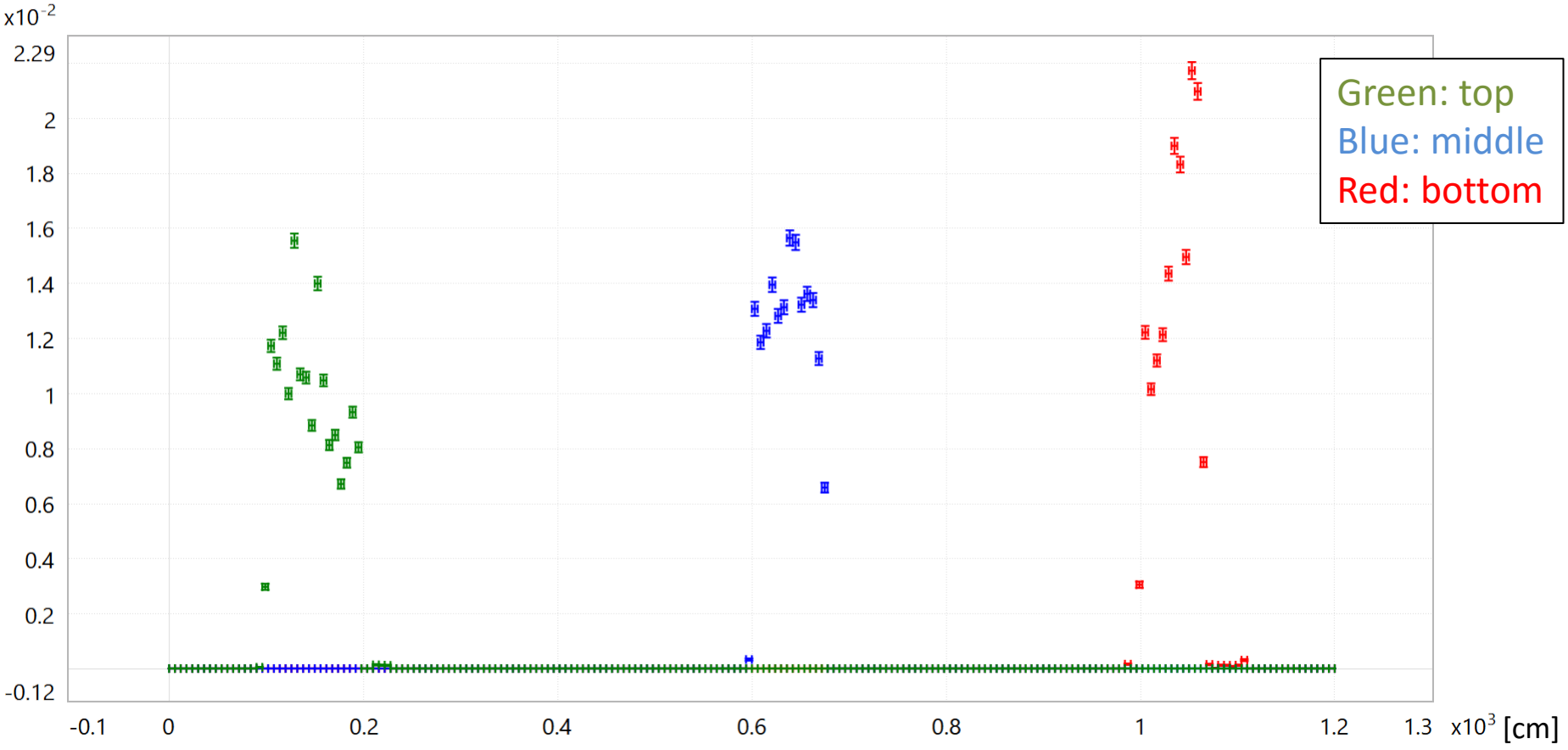
to save time: electron clusters,
default 600 electrons per cluster

electron clusters assigned to sim. channels (transverse diffusion), drift time smeared (longitudinal diffusion)

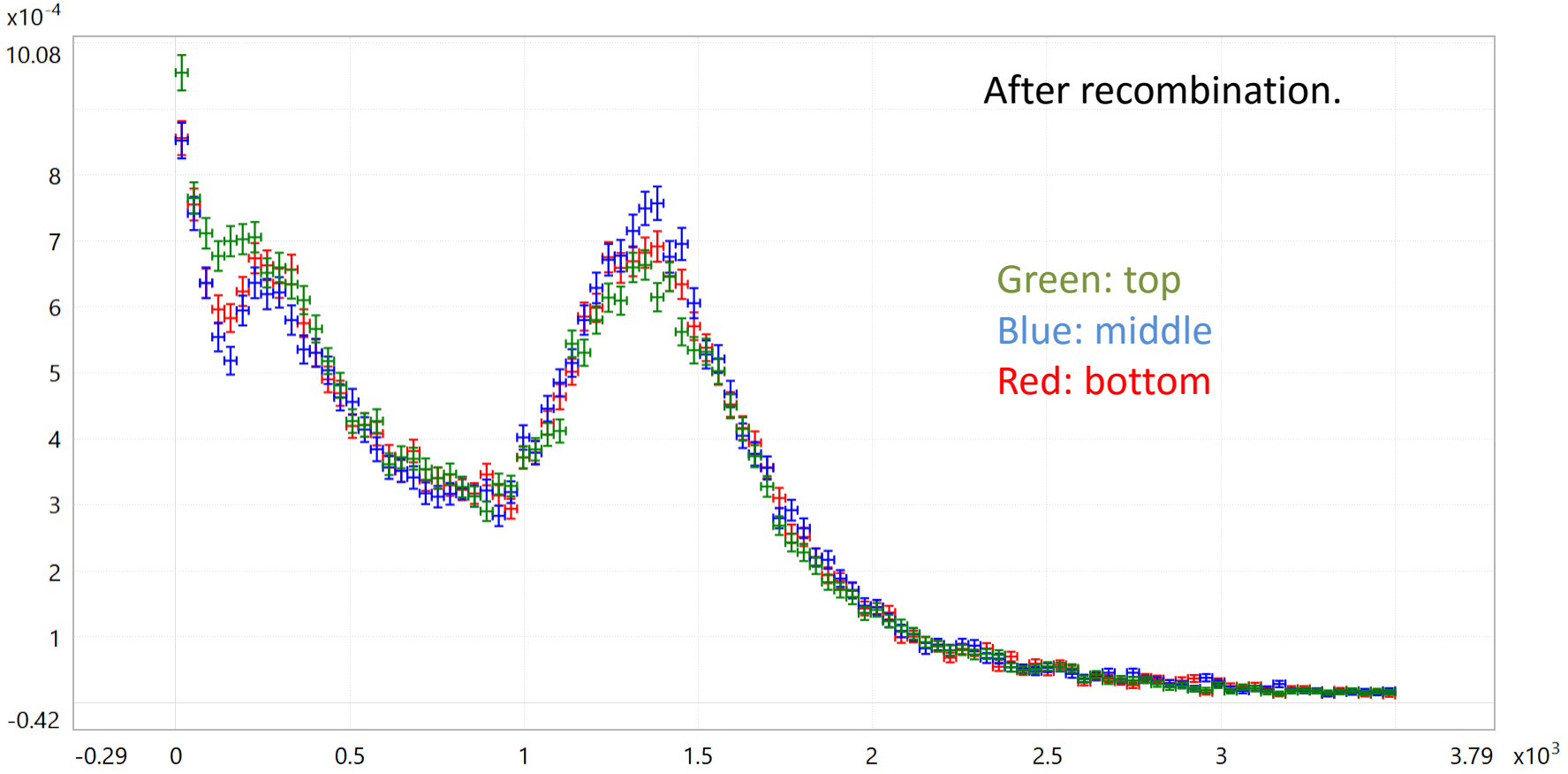
field & electronics response

ADC waveforms

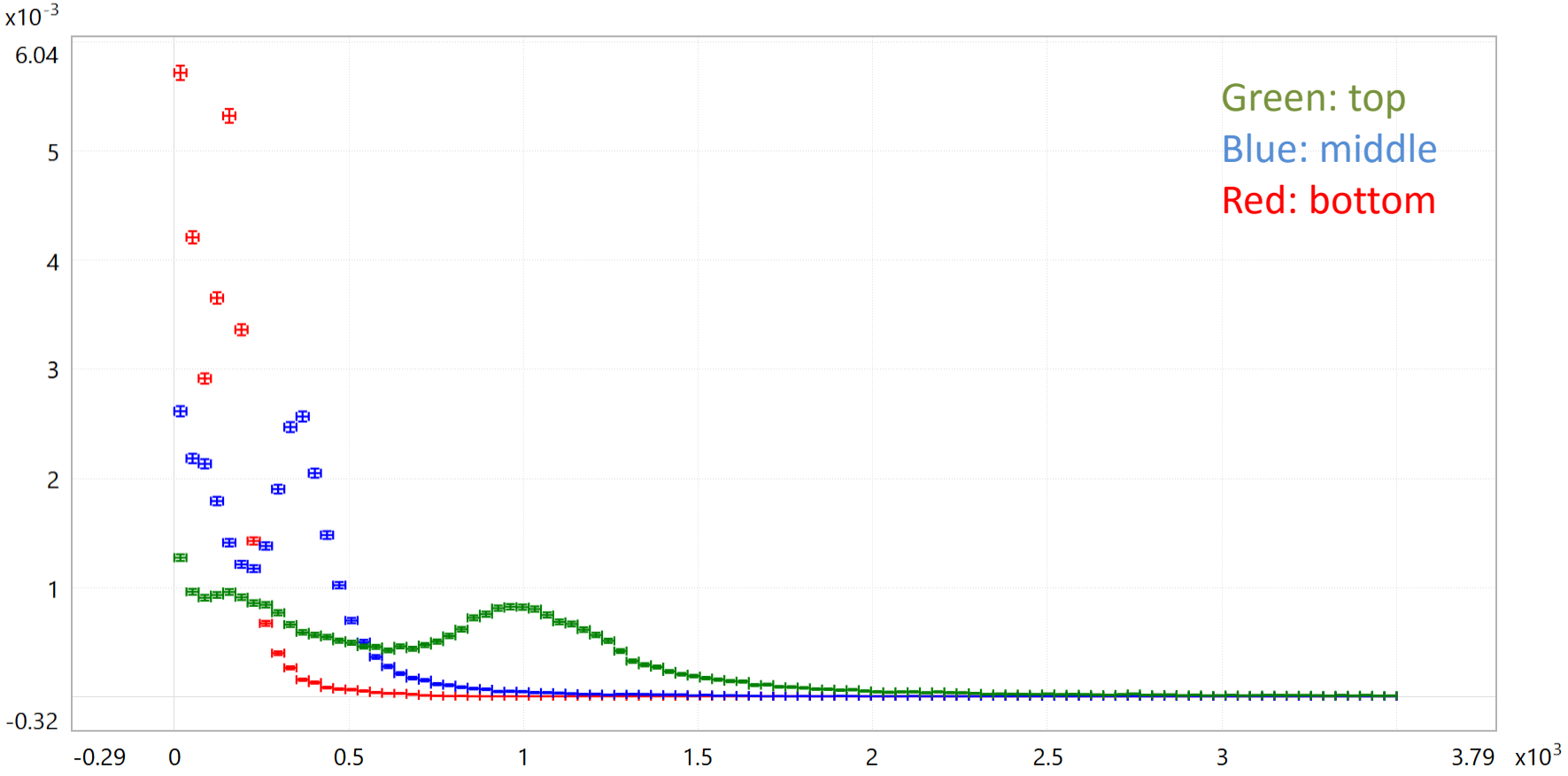
Voxel depth for simulated muons



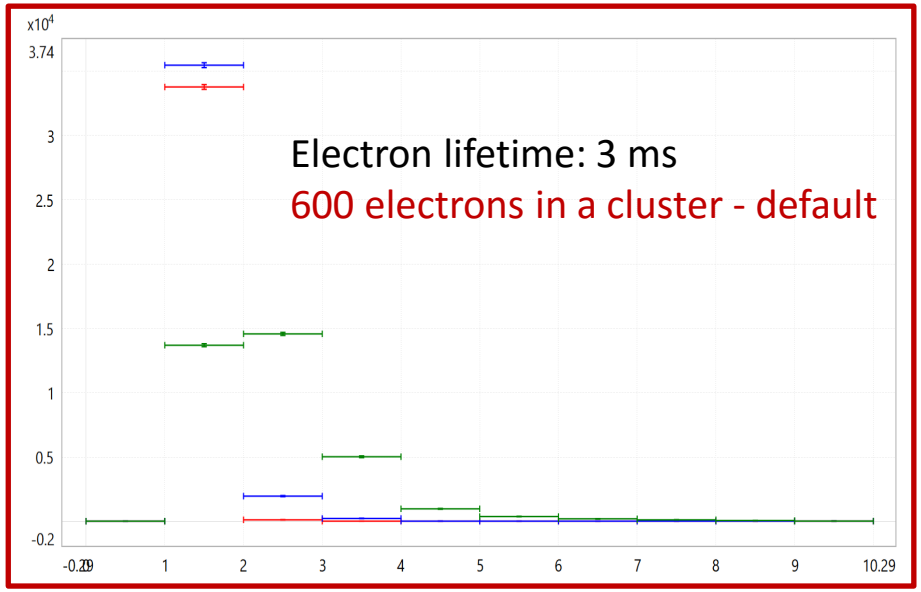
Number of ionized electrons

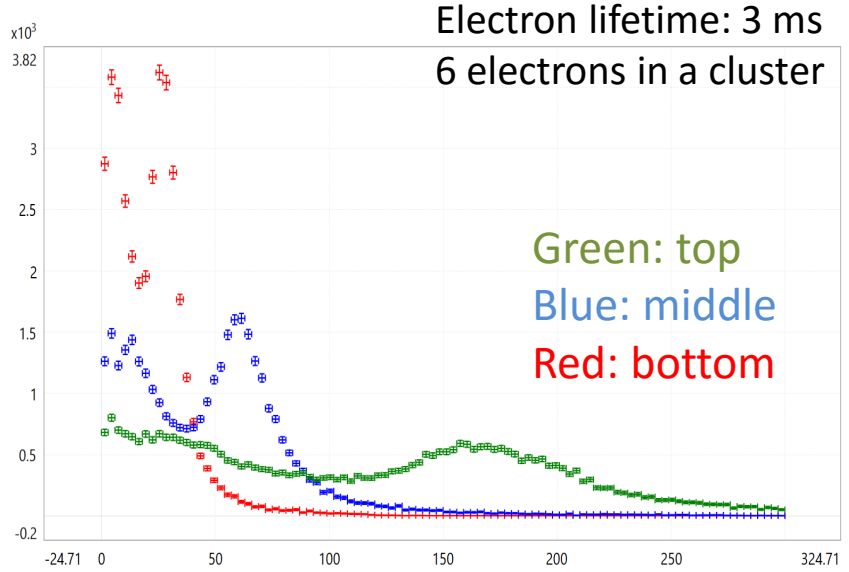


Number of electrons after attenuation due to electron lifetime

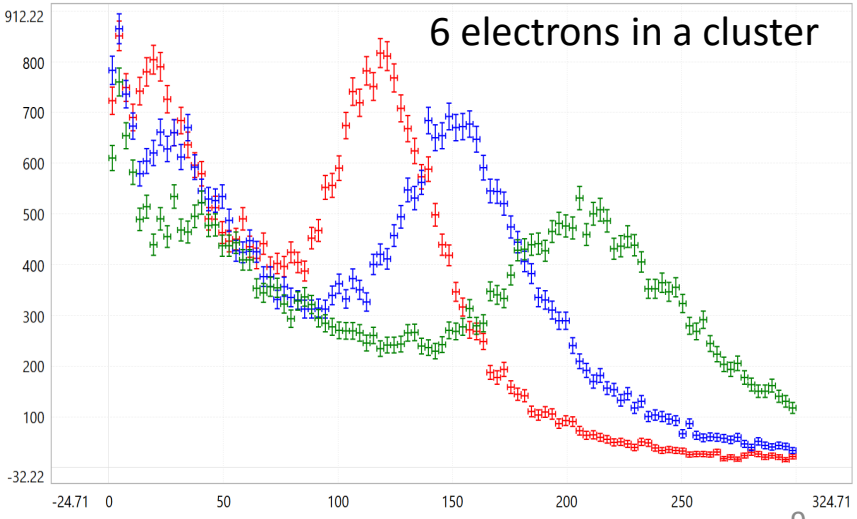


Number of electron clusters



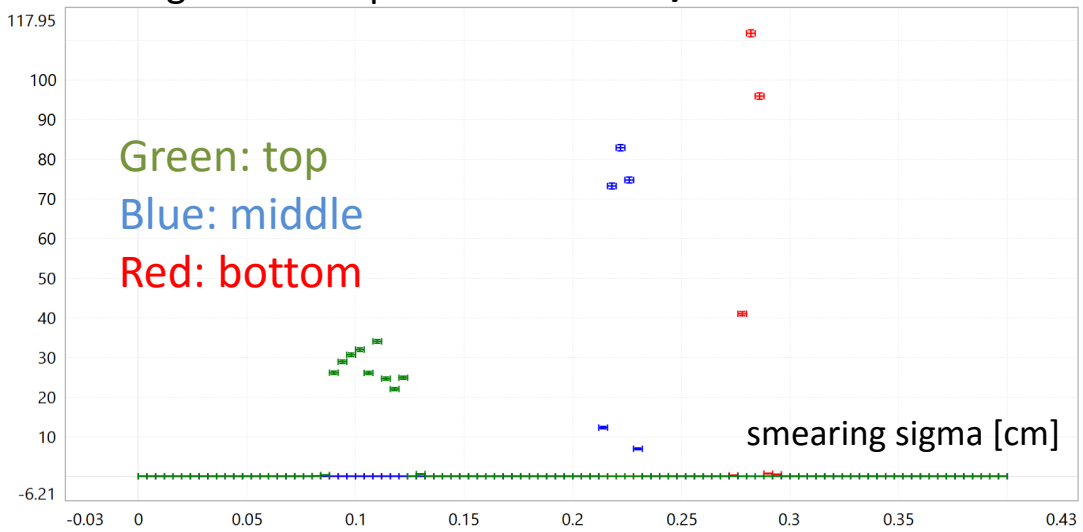


In the default configuration the number of electron clusters is 2-3. Diffusion smearing will distribute these clusters among channels → too high „quantization”.

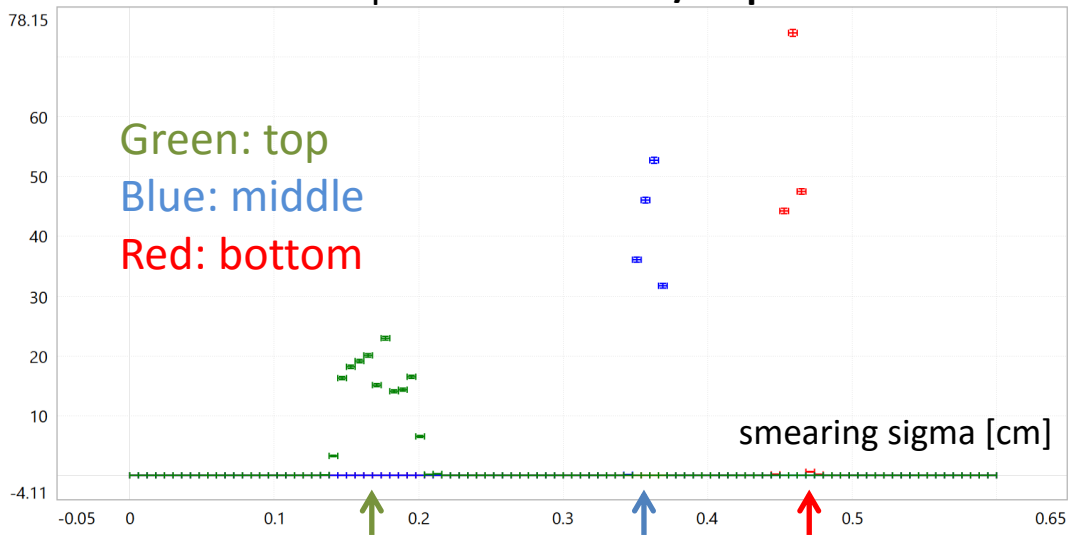


Diffusion scale

Longitunal component: level of **+/- 10 ticks**

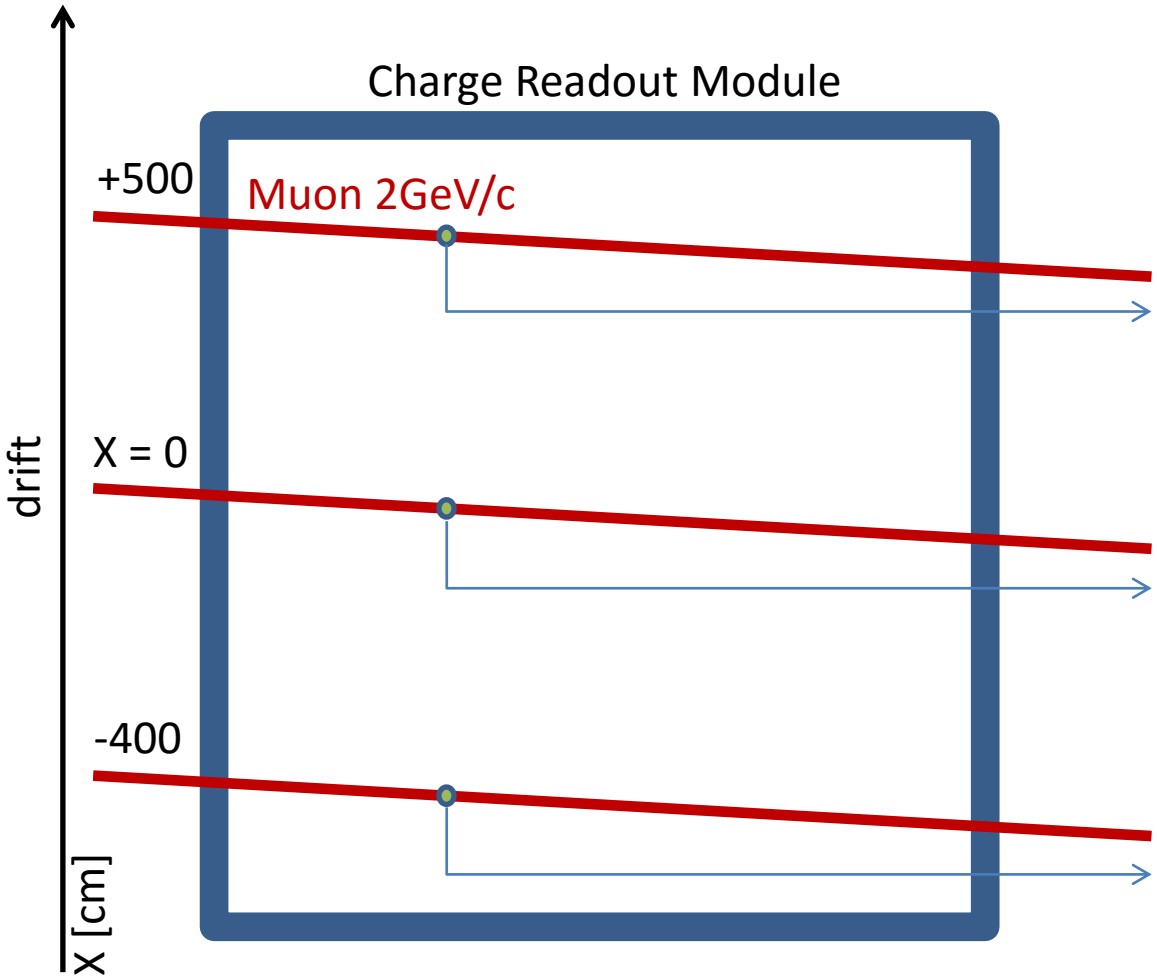


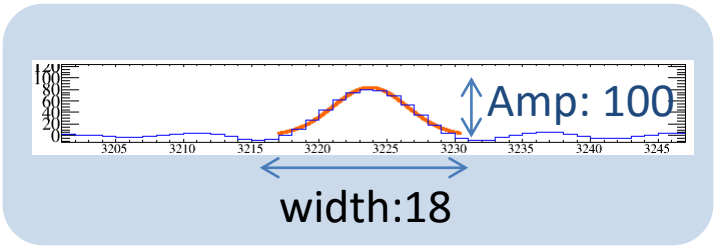
Transverse component: level of **+/- 2 pitches**

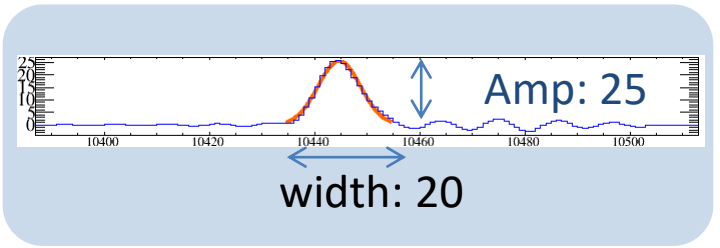


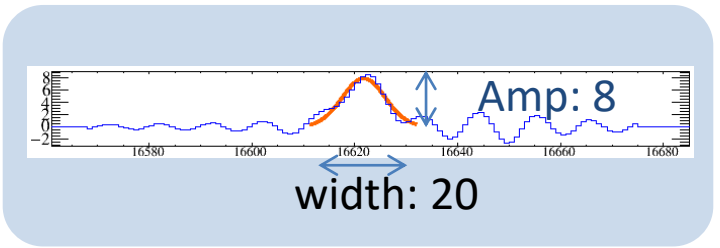
- Diffusion + default value of a number of electrons per cluster is not sufficient to make a proper gaussian shape.
- Instead spikes were created, resulting with more fluctuations in ADC waveforms.
- Change from 600 electrons in a group into 6 improved simulation.

Hit finding and hit fitting







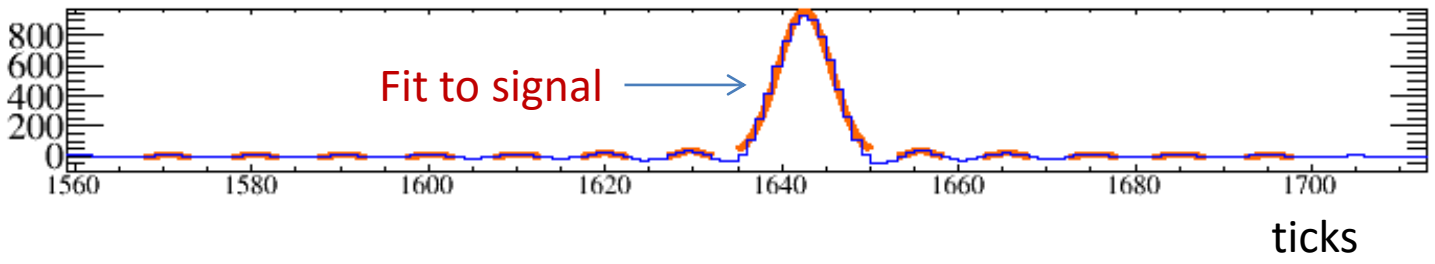


Muon 2 GeV/c, Θ_{0XZ} = -8 degree, Θ_{0XZ}=-11 degree

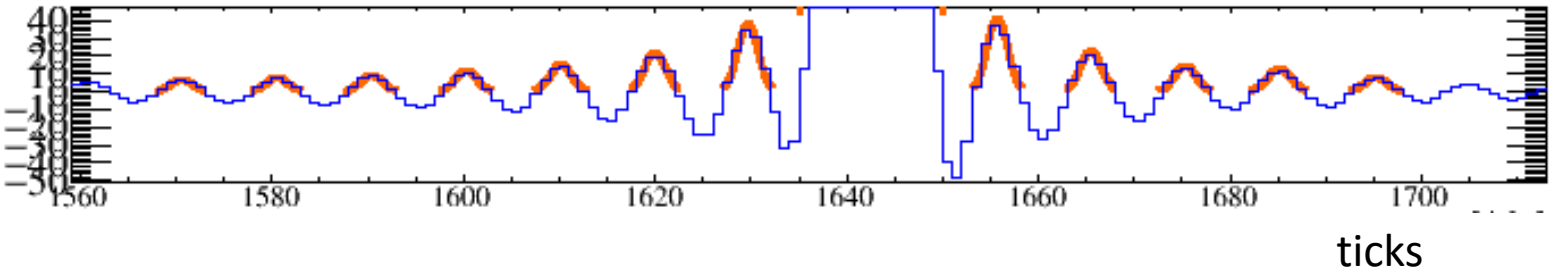
- Electron lifetime: 3 ms
- Diffusion ON

- Amplitude depends on the distance from CRM: ~exp(-x)
- Width also depends on the distance form CRM due to diffusion effect: ~sqrt(x)

Example of a signal



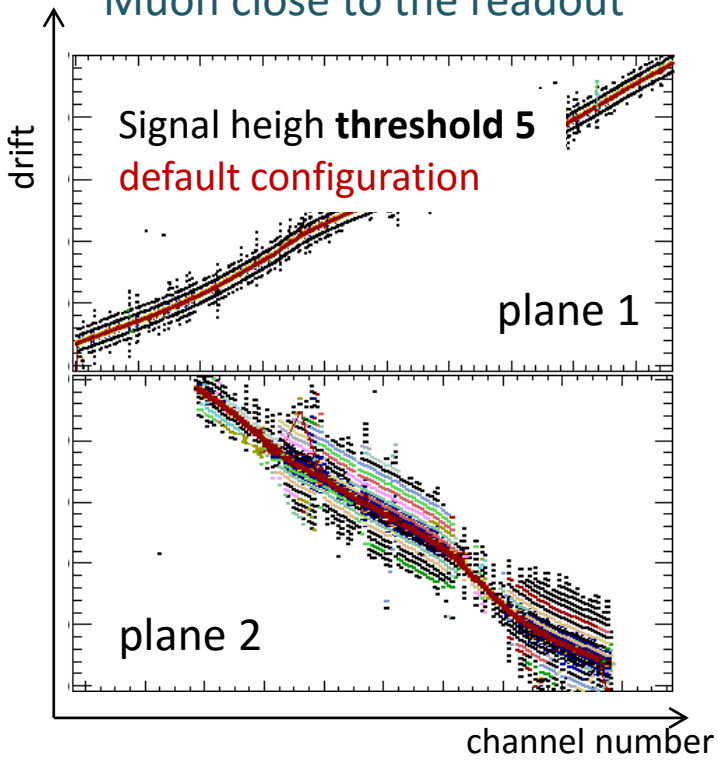
enlarged view

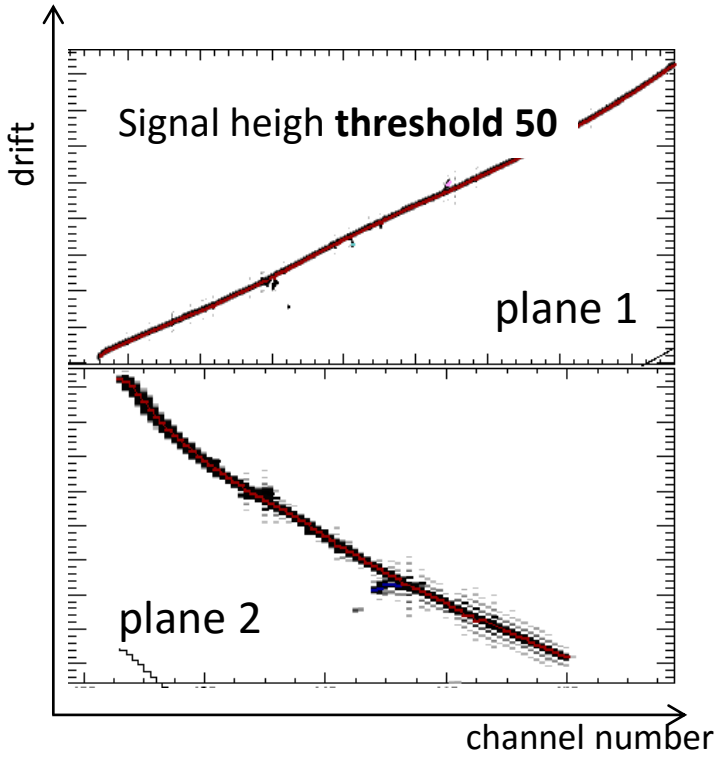


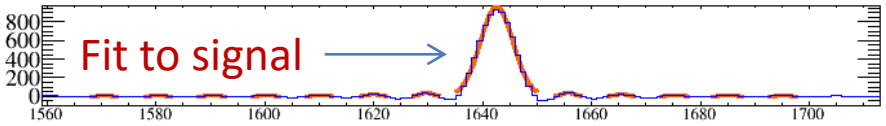
- Deconvolution is cutting a frequency entry if amplitude is below some threshold.
- DP electronics response seems to be longer (than SP) => more high frequencies removed.
- Small oscillations appear after deconvolution and cause difficulties in subsequent reconstruction.
- Simple threshold (now used in hit finding) not enough for highly varying signal amplitudes.
- One could try to fit signal without applying deconvolution.

Impact of hit fitting on 3D reconstruction

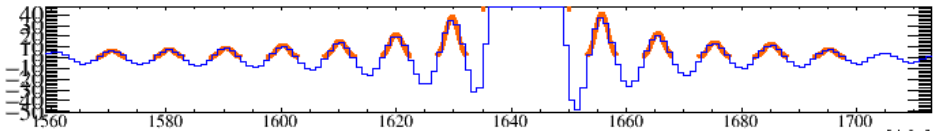
Muon close to the readout







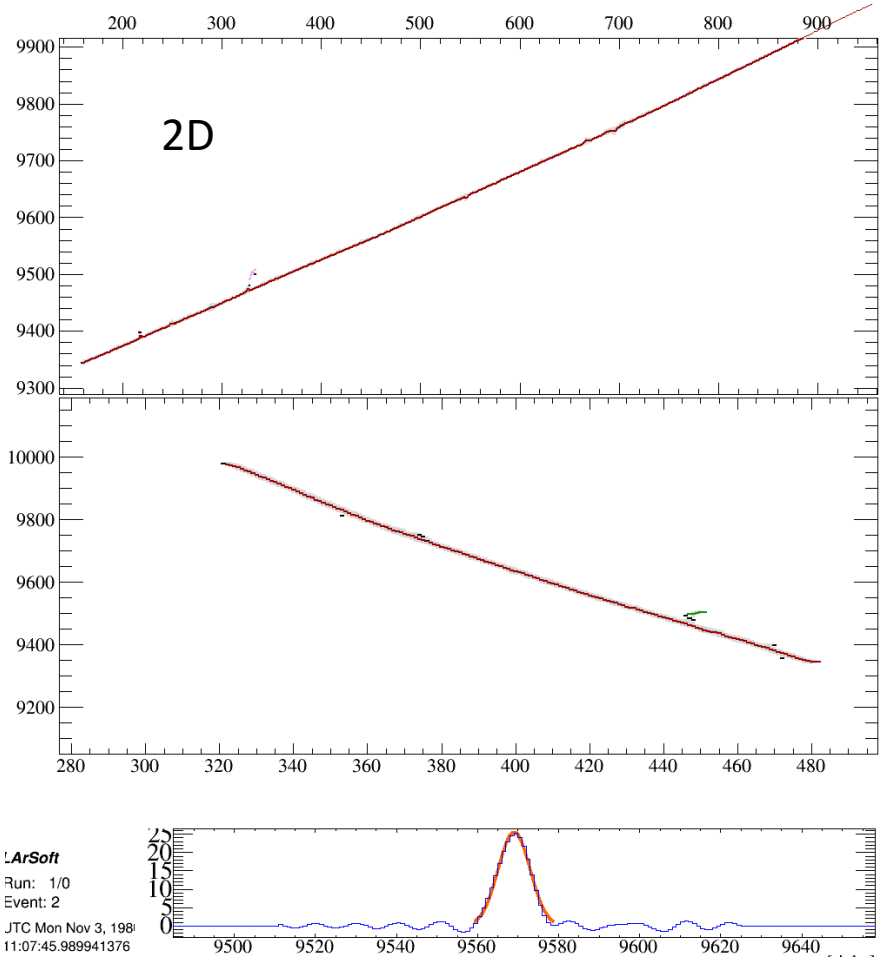
enlarged view

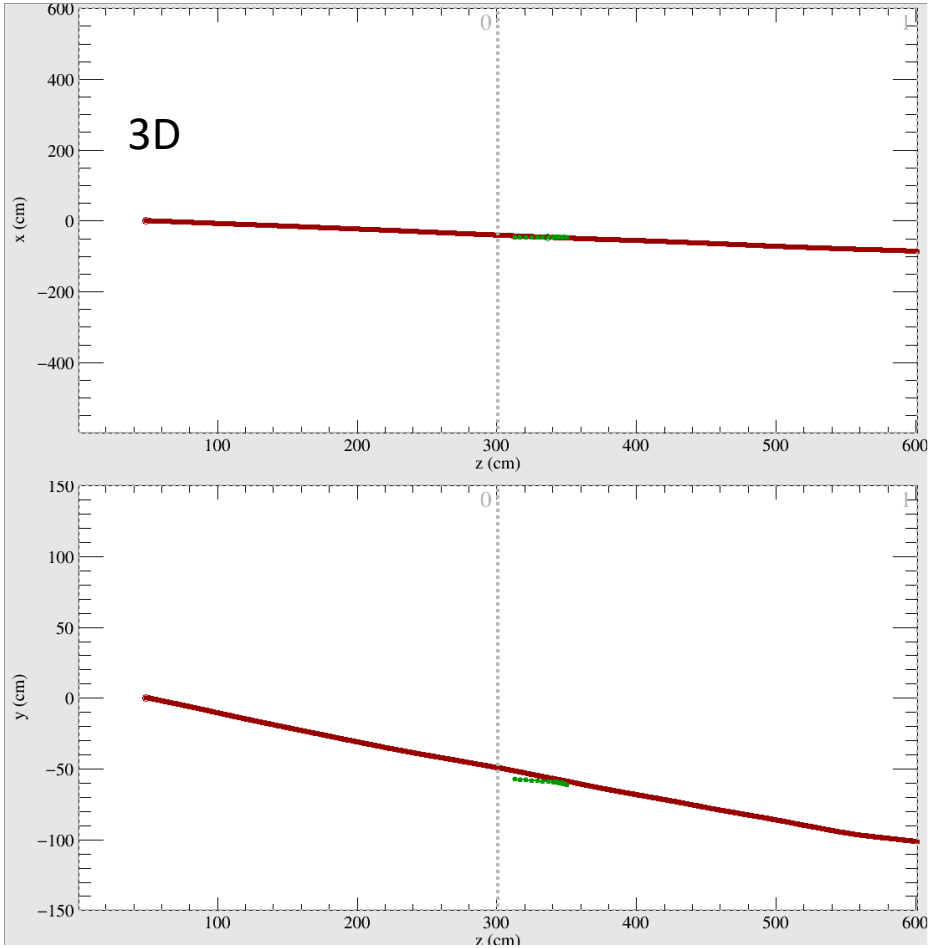


- Signal height threshold has to be tuned in order to have proper hit fitting. It results in different high threshold for different drift time and orientation w.r.t. readout channels.
- E.g.: muons close to CRM ~ 50.
- E.g.: muons close to cathode ~ 5.

Example of spatial reconstruction

once the signal heigh threshold has the proper value, spatial reconstruction works well.

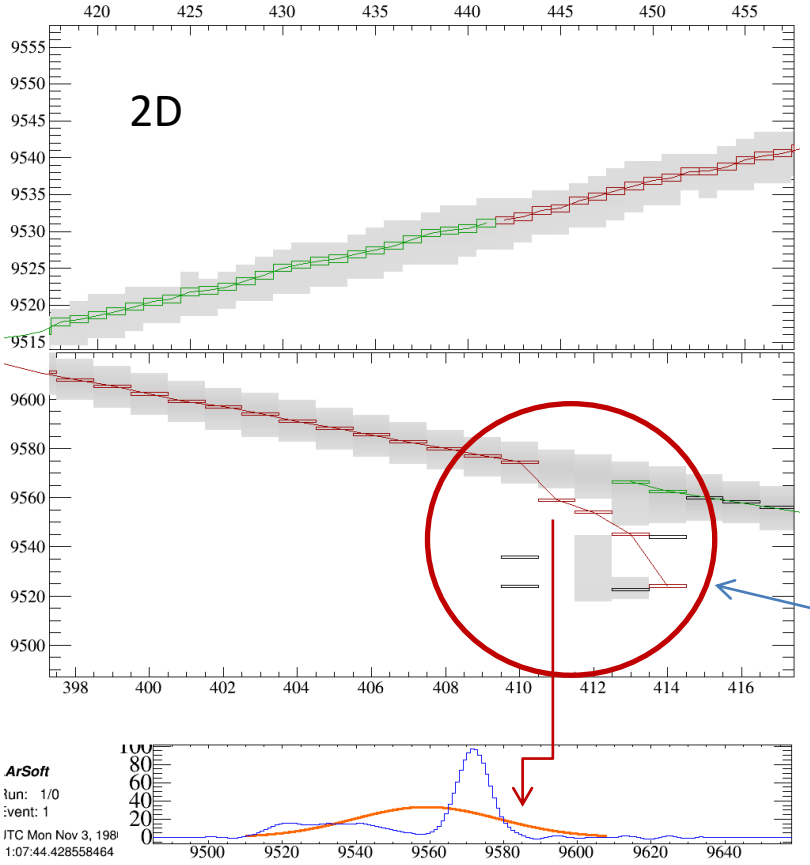


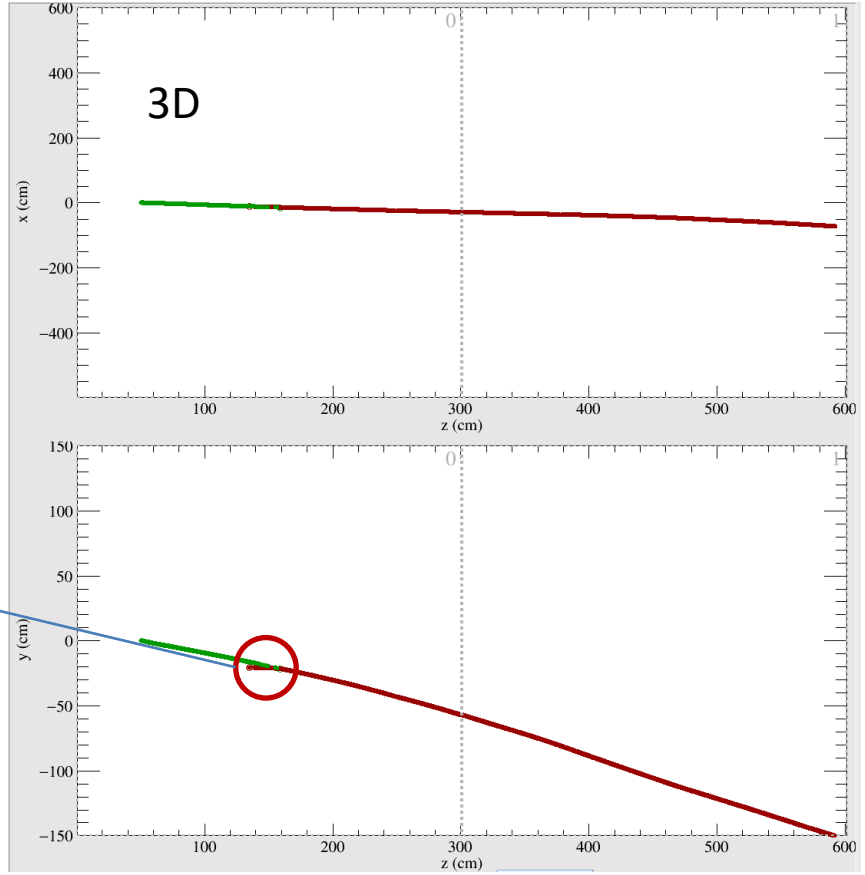


Reconstruction chain: gaus hit finder → LineCluster (2D pattern recognition) → Projection Matching Algorithm (3D trajectory fit and 3D pattern recogntion)

Spatial reconstruction which can be improved

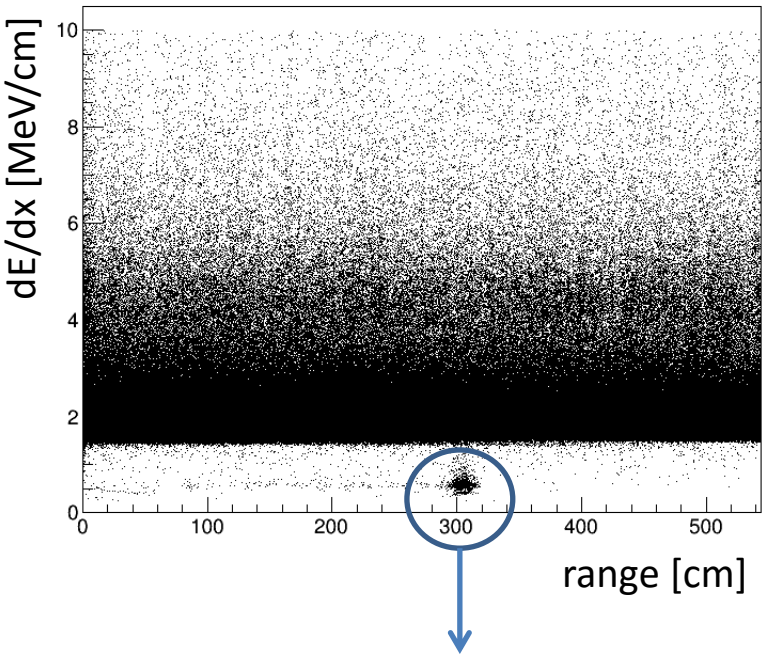
Reconstruction has some ineffiency which is also obeserved in SP but for now we do not have detailed comparison of reco-efficiencies between both technologies.



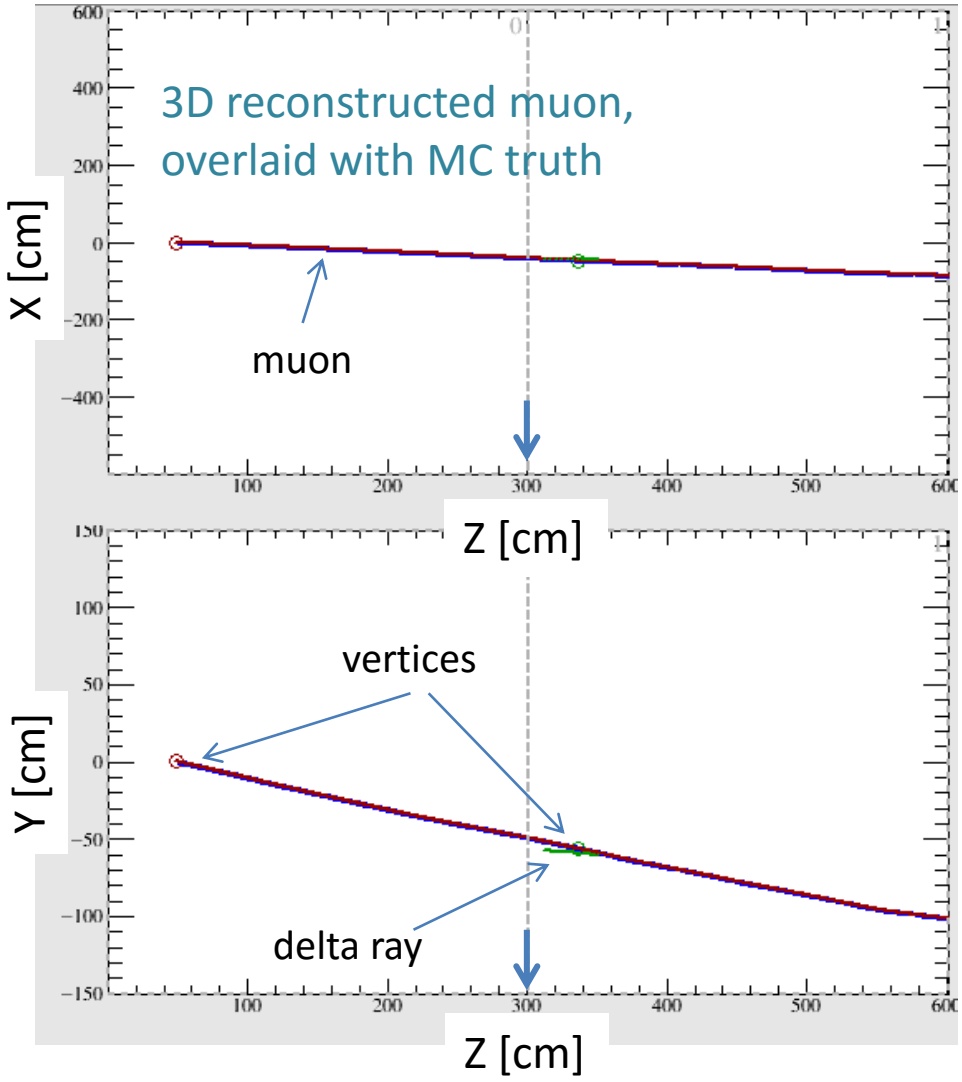


To be done: tunning parameters of cluster reconstruction, better hit finding.

dE/dx vs range

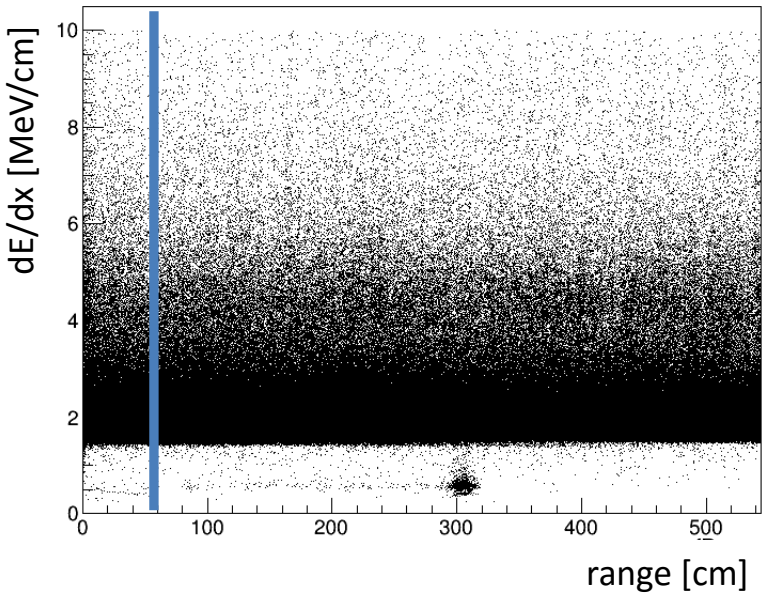


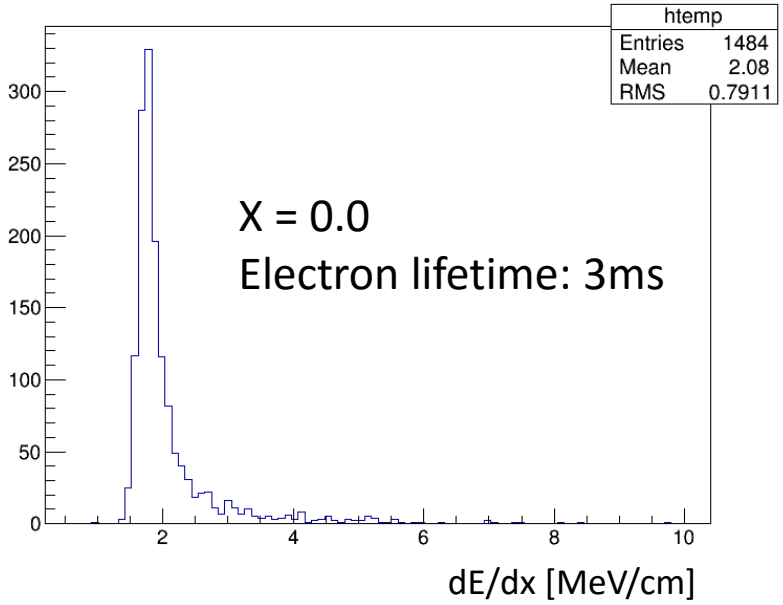
Around inactive region of CRM
(just a too simple dx calculation…)



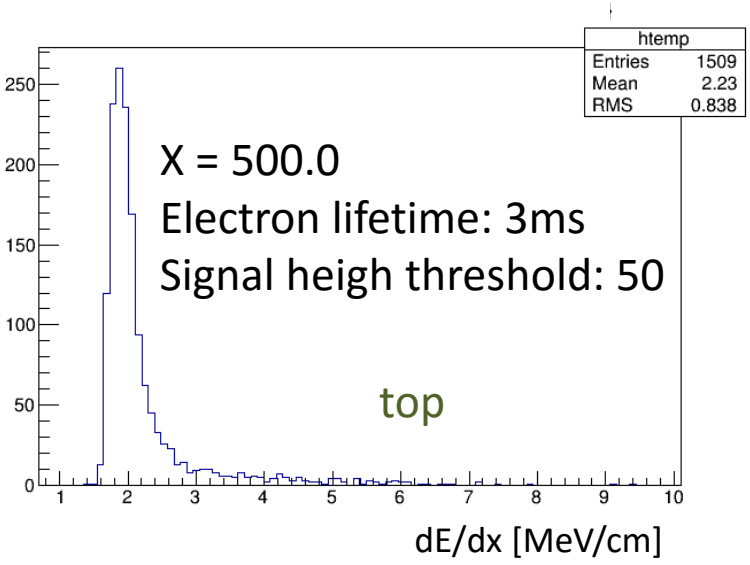
dE/dx vs range reconstruction

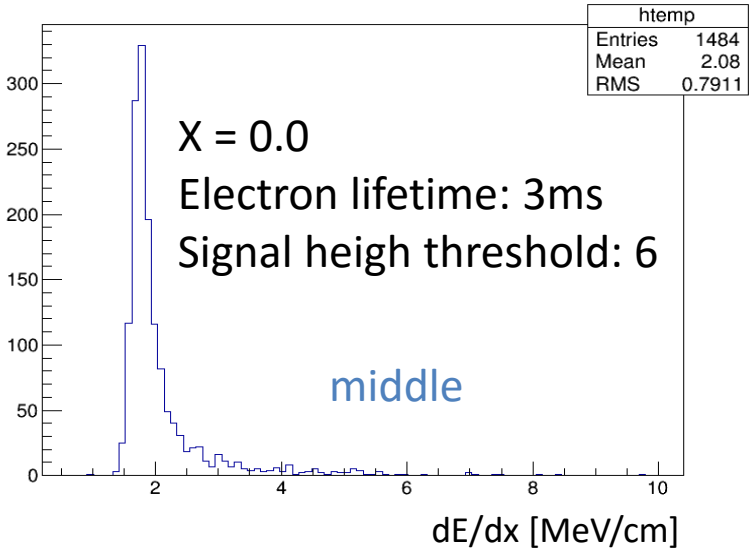
1. Conversion ADC to energy.
2. In DP there is single ADC to charge (electrons) constant for both planes.
3. Calibration constant is in larana/Calorimetry: CalAreaConstant, it was tuned to **4.966e-2** for DP (default for SP: [4.833e-3, 4.815e-3, 4.966e-3]).
4. Charge (dQ/dx) is converted to energy (dE/dx) using recombination formula.
5. The calibration constant can be tuned using dE/dx of reconstructed minimum ionizing muons (or stopping particles, or other methods based on well known and expected values of particles: see calibration tasks for protoDUNEs).

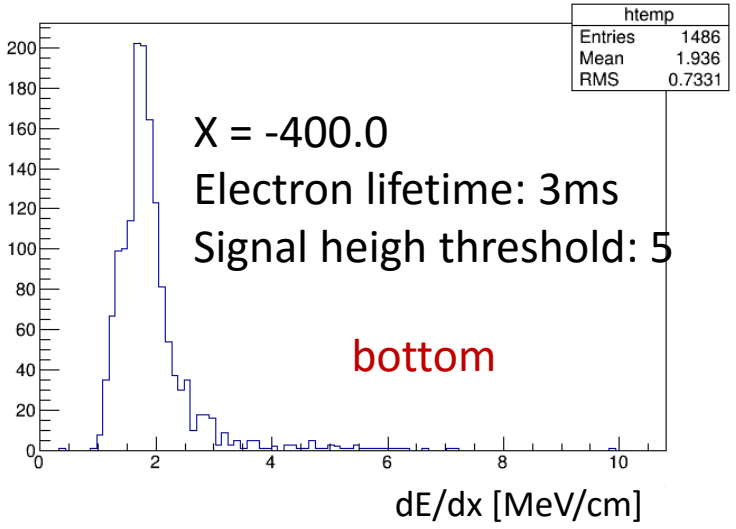




dE/dx vs range reconstruction

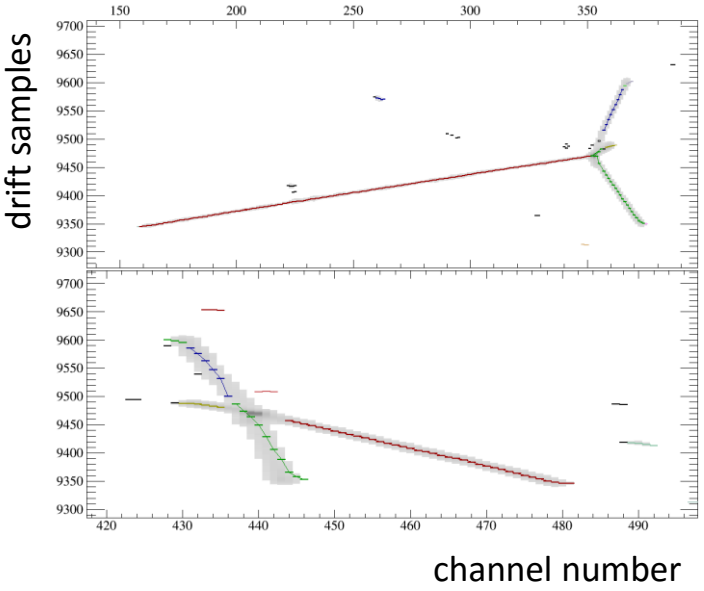


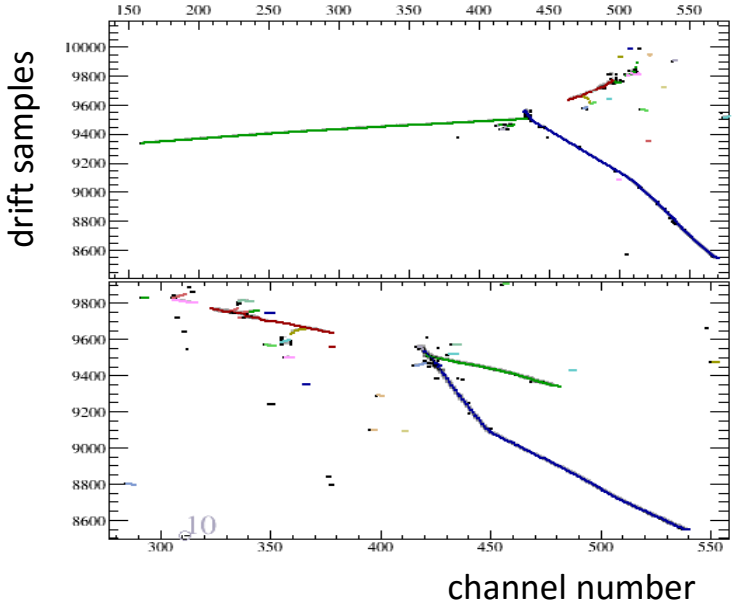


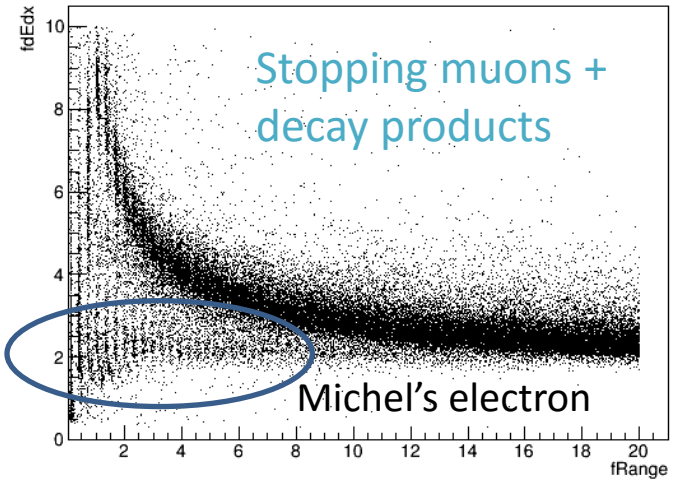


Other tests of reconstruction performance

2D projections of reconstructed event: proton @ 2 GeV/c







- Images above: color show association of tracks between views:
  - reconstruction of more complicated topologies seems to work correctly.
- One of the current reconstruction effort is to identify precisely the point of muon decay (important for calibration studies in protoDUNEs).

Summary of parameters

simulation

a. number of electrons in a group:

`services.user.LArG4Parameters.ElectronClusterSize:` 6

b. electron lifetime:

`services.user.DetectorPropertiesService.Electronlifetime:` 3000

reconstruction

signal height threshold:

`gaushit.MinSig:` [5, 5]

analysis

electron lifetime:

`services.user.DetectorPropertiesService.Electronlifetime:` 3000

Conclusion: are we ready for MCC 7 ?

- The major problem in the current software reconstruction arises from hit fitting in the deconvoluted signal.

- Possible solutions:
  - Change the fitting procedure, e.g. make fitting using raw (not deconvoluted) signal. Longer term task (one should add such method to LArSoft).
  - Set electron lifetime to high value to minimize amplitude variation in x direction. (Btw.: what reasonable max value can be expected?) This can be a temporary trick to provide reconstruction output to work on.

- Some minor tuning of higher level reconstruction algorithms may be expected to get best results on DP signals.

- We are thinking about involving more people who could be potentially interested in reconstruction and analysis. If possible, they could start working using samples from MCC7 (or even before).